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An Update on The effect of water stress on plants

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Abstract

Rarely optimal environmental conditions of the plant are available, from water, air and nutrients, Water stress often occurs due to lack of soil moisture or other factors may pay organisms to limited survival. The study of plants under these conditions and knowledge of how the plant responds to water stress on the basis of changing life and physiological processes, so this review describes some aspects of the changes caused by water stress in germination, morphological, physiological and productivity composition in higher plants.

Introduction

During natural plant growth, plants are frequently exposed to a variety of environmental challenges, including heat, oxidative stress, salinity, flooding, drought, and heavy metal toxicity [1, 2]

Okumura *et al*, [3] defined stress as every external hindrance that reduces productivity to lower limits than what the genetic capabilities of the plant are supposed to achieve. Okumura *et al.*, [4], Okumura *et al.*, [5]. They were more accurate, as they defined stress as any force or every harmful effect that disrupts the normal activity of any plant system.

One of these environmental stresses is drought, a meteorological term that is generally defined as a period without heavy rainfall [6]. Drought stress generally occurs when the available water in the soil is reduced and weather conditions cause constant water loss by transpiration or evaporation. [7]. Drought stress tolerance is observed in

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almost all plants, However, tolerance varies between species and even within species. [8].

Drought or water stress prevents cells swell more than cell division [9]. It reduces plant growth by affecting many physiological and biochemical processes, such as photosynthesis, respiration, translocation, ion uptake, carbohydrate, nutrient metabolism and growth stimulators [10]. Severe water stress causes metabolic arrest and disruption, and finally plant death [7].

So our study of the physiology of stress will contribute to increased understanding of the factors that determine the distribution and spread of plants and actual changes in various processes during the life cycle of growth. In the applied agricultural aspect, the ability of crops to maintain viability and the required plant density under stress conditions is a major factor in determining the economic yield.

Effect of water stress on seed germination.

Germination is an essential process in plant development to obtain optimal seedling numbers that leads to higher seed yield [11,12 ,13]. One of the most important stages of plant growth is often affected by environmental stresses including drought [14]. Water absorption is the first stage of germination where live and dead seeds absorb water and swell. The amount of water absorbed depends on the chemical composition of the seeds. Proteins, mucilage and pectin are more hydrophilic colloids and absorb more water than starch [15].

Water is the main factor that stimulates germination and the potential water environment affects the rate of water absorption and thus on germination. With the increase in the severity of drought, the percentage of germination and the rate of germination decrease [16].

Some plant species have been studied at Kastamonu gardens and parks to see how well they tolerate drought stress. Studies were carried out to determine the effect of increasing water stress on seed germination rate. The results showed that as water stress increased, the percentage of germination decreased in all tested species [17].

Effect of water stress on proline in plants.

Proline has a role in protecting plants from moisture stress, as it acts as an osmotic regulator that protects plants from stress by maintaining the stability of membranes and enzymes, and as an antioxidant [18].

The phenomenon of proline accumulation can be used as a measure of moisture stress tolerance. Under moisture stress conditions for wheat plants, proline accumulation occurs and its percentage increases with the duration of stress [19]. Relatively high concentrations of proline may be non-toxic to the cell, so they are called compatible solutes, which act as enzyme protectors under conditions of salinity or drought, as well as maintaining the structures of large molecules and organelles inside the cell [20].

Khan *et al.*, [21] found in a study conducted at the Institute of Biotechnology and Genetic Engineering at the Agricultural University in Peshawar to know the effect of water stress on the tomato varieties grown in the greenhouse. the result was that The plants irrigated with full irrigation level (100%) were significantly superior in moisture content and length and the lowest proline content in the leaves reached (4.4 mg 100 g), while the leaves content of proline increased to (5.8 mg 100 g) in plants subjected to water stress (watering for three days and then withholding water for two weeks).

Qayyum. [22] found that the content of proline increased with the increase of osmotic potential in wheat seedlings at 14 days old from 0.33 mg.gm in the control treatment (without stress) to 2.65 mg.g at -8 bar of osmotic potential.

Finally, in previous studies, two irrigation parameters, i.e. 100% and 60% field capacity (FC) were used to understand the effects of water deficiency on proline metabolism of five sunflower (Helianthus annuus L.) cultivars. The result was an increase in the content of proline in the event of water shortage in the roots, stems and leaves of all cultivars [23].

Effect of water stress on soluble carbohydrates

Drought tolerance may be due to the gradual use of starch savings; Many researchers pointed to the protective role that soluble carbohydrates play at the level of membrane systems in general and mitochondrial membranes in particular [24,25].

In addition, soluble sugars contribute to protecting the phenomena (reactions) leading to the formation of Enzymes are the thing that allows the plant to better withstand the effects of drought [18]. Ali dib *et al.* [26], noted that the changes in the soluble carbohydrates content of wheat are much weaker than for proline, and that the largest percentages are recorded from the twelfth day (12) of water stress. As for the results that were reached by Adjab, [27] during his titration of carbohydrates in the fifth leaf of five varieties of durum wheat, they showed that the latter showed a weak accumulation of them (soluble carbohydrates). Carbohydrates and proline with other substances contribute to the phenomenon of hydrolytic modification that protects membranes and enzymatic systems by reducing their hydrolytic potential to compensate for the low water potential of the leaves [28, 29].

Effect of water stress on chlorophyll content and photosynthesis in leaves.

The chloroplasts are the centers of photosynthesis in the plant, in which the chlorophyll molecules and other pigments are organized. The chlorophyll pigment is among the most important natural pigments in the plant. This pigment has the ability to absorb light energy and convert part of it into chemical energy [30].

Maxwell and Johnson, [31], showed that the highest content of chlorophyll in wheat plant was 51.73 unit spad in alluvial clay soils, and the lowest content of 47.51 units spad in mixed soils. It was noted [3] in Ghana when they studied the effect of water stress on some characteristics of tomato yield. The relative content of chlorophyll in leaves increased significantly when treated with full irrigation (100% of field capacity) as it reached 53.61 sepals compared with plants irrigated at the 40% level of field capacity (49.37 units spad).

Hossain, [33] noticed a significant decrease in the concentration of chlorophyll pigment as a result of the wheat plant being exposed to water deficiency in the different stages of growth. Keyvan, [34] noticed a significant decrease in the chlorophyll content of wheat cultivars when exposed to moisture stress and this decrease increased with increasing the level of moisture stress. Al-Rahbawi, [35] found that the use of water amount of 15 liters* to irrigate plants produced the highest values compared to the amount of water 5 liters. The average content of chlorophyll a was 0.5 mg/g-1 at an irrigation period of 20 days between irrigation and another, with an increase of 33.3% compared to the control treatment of 0.36 mg/g. The moisture treatment 75% was significantly superior to the rest of the moisture 25 and 50% treatments, as it gave the highest average amount of chlorophyll amounting to 888.8 micrograms of maize plant [36].

Many studies have confirmed the effect of water stress on the various reactions of the photosynthesis process [37]. In general, the researchers believe that this is done in two ways: either by increasing the stomatal resistance, which determines the diffusion of C02 gas into the leaves and from which the photosynthesis rate is determined, or by affecting the rate of photosynthesis and Metabolic reactions at the cell level and its responsible organelles [38]. The stomata and other cells in the case of water stress reduce the rate of photosynthesis in wheat, by closing the stomata reducing the leaf area and reducing water loss, which leads to a reduction in yield [39,40,41]

Zhang *et al.*, [42] George-Jaeggli *et al.*,[43] Also, severe water stress directly affects the functioning of the photosynthetic chlorophyll systems and leads to a decrease in the chlorophyll content of leaves

Stomatal response to water stress

The response of the plant to severe water shortage is by closing the stomata in order to reduce transpiration and water loss from leaf surfaces to a level that allows reprocessing of the same level of water lost through the roots. This is the case observed in all plants alike. Whether it is desert plants or plants of temperate or dry areas, where the mechanism of opening and closing stomata is completely dependent on relative humidity [44 , 45]

It is understood from this that any change in the water content of the soil is inevitably linked to the transpiration process. The stomata that controls transpiration provide a mechanism to protect the plant from any shortage of water content or stock, and thus the stomata will close at a certain rate that depends on the percentage of water shortage in the soil or That some plant species close their stomata completely and more than other plant species, especially when the soil water shortage develops, or that the stomata in some species do not carry out the transpiration process even after soil irrigation. These concepts may differ relatively when referring to C4 plants or succulent plants that store water in modified leaves as in cacti [46, 47, 48].

Unfortunately, in many plant species, especially food crops, the surrounding epidermal cells and the surface of the guard cells are not protected by a thick layer of the cuticle, so water loss occurs directly from the guard cells to the atmosphere. If the average amount of water evaporating from the surfaces of the guard cells is greater than the amount that is compensated by the mesophyll cells under the epidermal cells, the guard cells will become flaccid and close the stomata. In other words, the guard cells function as if they were an osmometer [49,50]. The process of stomata closing is regulated by the so-called hydro active processes. That is, the life processes of this stomatal closure depend and mainly use the reverse ionic signals that cause the stomata to open. The alertness occurs by closing the stomata when the leaf water potential decreases in the mesophyll cells, and signs of the use of ABA (abscisic acid) and other hormones appear. Since the discovery of abscisic acid in the late sixties, it has been known that this acid plays an important role in the process of closing the stomata caused by a lack of water. The accumulation of ABA in leaves that suffer from water stress, as well as the external applications of abscisic acid as an inhibitor of stomata opening process [47].

In a study on two mutants of tomato that failed to collect the normal level of abscisic acid, they were exposed to wilting very quickly due to lack of water. The confirmed role of ABA in closing the stomata of plants exposed to moisture stress is difficult to detect and confirm to this day because the presence of ABA is often found in high concentrations in tissues that are not subjected to tension. ABA. In most well-irrigated plants, ABA is synthesized in the cytoplasm of the mesophyll cells in the leaves, but due to the acidity gradient (pH) between the mesophyll cells, the abscisic acid is synthesized and accumulated in the chloroplast cells [47,51].

As for how abscisic acid controls the swelling of the guard cells, it remains limited, as practical evidence has shown that abscisic acid does not need to enter the guard cell, but it may be present on the outer surface of the plasma membrane, as it was known that the mesophyll cells that are linked by ligands or the plasmodesmata bridges, there are no such bridges with the guard cells, that is, the absence of links between the guard cells and the mesophyll cells, which might have allowed the crossing of ABA to the guard cells. Therefore, the accumulation of large quantities of in a study on two mutants of tomato that failed to collect the normal level of ABA, they were exposed to wilting very quickly due to lack of water. The confirmed role of ABA in closing the stomata of plants exposed to moisture stress is difficult to detect and confirm to this day because the presence of ABA is often found in high concentrations in tissues that are not subjected to tension ABA. In most well-irrigated plants, ABA is synthesized in the cytoplasm of the mesophyll cells in the leaves, but due to the acidity gradient (pH) between the mesophyll cells, the abscisic acid is synthesized and accumulated in the chloroplast cells [51].

in withered leaves, means that the stomata closure that begins before any significant increase in the concentration of ABA is explained by the release of ABA stored in the apoplast, where the process of stomata closure occurs at an early period and with a sufficient amount of ABA. It is known the role of abscisic acid, the role of hormones is also great in the process of communication between roots subject to water stress and leaves. In experiments on yellow maize, an increase in the production of ABA was obtained as cytokinins prevented stomata closure [51].

Effect of water stress on morphological parameters:

The studies that examined the root traits under water stress are few despite their importance in drought resistance. The shape of the root system varies from plant to plant since it is governed by genetic type and is intimately tied to soil and climatic conditions [52]. The number of roots is greatly affected in the case of water deficit [53]. It was concluded Nahar and Gretzmacher, [54] in its study conducted in Austria to assess the impact of water stress on tomato roots using four levels of drip irrigation water (20 minutes, 25 minutes and 30 minutes in addition to the comparison level full irrigation). The study showed significant differences in Irrigation levels for root length, wet and dry root characteristics.

The leaf is the organ most impacted by water stress, when the blade's development slows, it twists, and once the plant flowers, its leaves swiftly deteriorate [55]. The impact of water stress was observed by measuring the length of the final

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leaves [56]. This criterion, according to this researcher, can be essential in understanding the mechanism of water stress resistance; Also, water stress reduces the leaf area, ie the light-receiving area, which negatively affects the building of organic compounds.

For all plants, drought decreases the size and diameter of the stem, the length of the internode, and the quantity and area of the leaves [57]. The sensitivity of the leaf area to moderate water stress is an adaptive mechanism that contributes to the transfer of substances represented for root growth and thus improving the water condition of the plant [58]. Nemmar, [59] studied on sunflowers, and found that the water deficit during the vegetative phase significantly reduces stem length and inhibits the synthesis of dry matter. The results obtained by Adjab, [27] in a study on five wheat cultivars, which were exposed to increasing levels of water stress, showed that the more severe the latter, the more the leaf area was reduced.

Wahb-Allah, [60] studied on the effect of resistance of tomato genotypes to water stress under protected cultivation conditions, using irrigation levels of 20%, 40%, 60% and 80%, and the comparison level of 100% and 120% of evaporation .found that transpiration, as water stress significantly reduced plant height, stem diameter and leaf dry matter content. The level of irrigation exceeded 120% with a plant length of 94.5 cm. Also, there was no significant difference between the irrigation level of 100% and 120% in the characteristics of the percentage of dry matter in leaves and stem diameter.

Effect of water stress on reproduction and maturation

Some studies have shown that the period between flowering and maturation is the most sensitive to water stress, and the most important symptom of this is the phenomenon of Glaucescence , which leads to a significant reduction in yield [61]. The spike also reduces the vitality of pollen, which was also observed due to a lack of water and nutrients [62]. As for the water deficit that occurs at the stage of maturity, it is completely unsuitable, as it significantly reduces the weight of 1000 grains , and this is affected by the process of filling the grains as a result of slowing or stopping the migration of composite materials in the leaves, which may represent the main reason for the limitation of the final yield .

Ozbahce and Tari, [63] observed the effect of planting distances and water stress on the quality and yield of tomato under semi-arid climatic conditions by studying the effect of four levels of irrigation 25%, 50% and 75% and the comparison level 100% of evaporation and transpiration, as the results showed significant differences between irrigation levels. The level exceeded 100% at the average fruit weight and diameter, as it reached 54.29 g and 45.25 mm, respectively, while it decreased to 28.68 g at the 25% level and 39.00 mm at the 50% level.

Fadol et al., [64] conducted a field experiment for two consecutive seasons with the aim of studying the effect of irrigation periods on the growth and productivity of six cultivars of the Egyptian fava bean plant. Four levels of the water system were compared stop irrigation at (10-10) fixed and (10-20) and (10-20) and (20-20) days were studied for the characteristics of height, number of pods per plant, number of branches per plant, seed production per hectare and weight of 100 grains .The results showed that stopping irrigation (prolonging the irrigation period) during the growth periods under study It led to a decrease in plant height, number of branches or number of pods and seed productivity, and it was found that this decrease was significant when water stress occurred at a period of 20-20 days compared to irrigation period 10-10 days after flowering. The results showed that there were significant differences in plant height and weight, One hundred grains and the number of pods per plant.

Conclusion

Stress caused by water stress negatively affects all stages of plant life, beginning with the stage of germination, vegetative growth, physiological processes and reproduction, and consequently on the yield in all types of plants. Depending on the stage of growth.

Conflict of interest

There is no conflict of interest among the authors

Consent for publications

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Reference

1. Jaleel CA, Manivannan P, Kishorekumar A, Sankar B, Gopi R, Somasundaram R, et al. Alterations in osmoregulation, antioxidant enzymes and indole alkaloid levels in catharanthus roseus exposed to water deficit. Colloids and Surfaces B: Biointerfaces. 2007;59(2):150–7. doi:10.1016/j.colsurfb.2007.05.001
2. Nakayama N, Okumura M, Inoue K, Asakawa S, Kimura M. Morphological analysis of viral communities in the floodwater of a Japanese paddy field. Soil Biology and Biochemistry. 2007;39(12):3187–90. doi:10.1016/j.soilbio.2007.06.025
3. Okumura M, Inoue K, Asakawa S, Kimura M. Turner N.C., (1986). Adaptation to water deficit. A changing perspective. AUST. Plant. Physiol. 13: 175-180. Soil Biology and Biochemistry. 2007;39(12):3187–90. doi:10.1016/j.soilbio.2007.06.025
4. Okumura M, Inoue K, Asakawa S, Kimura M. Jones H.G, et Jones M.B., (1989). Introduction: Some terminology and common mechanisms. In: Jones T.J; Flowers M.B. Jones (Eds), Plantsunder stress. Cambridge Univ.Press, pp: 1-10. Soil Biology and Biochemistry. 2007;39(12):3187–90. doi:10.1016/j.soilbio.2007.06.025
5. Okumura M, Inoue K, Asakawa S, Kimura M. Kranner, I., Minibayeva, F. V., Beckett, R. P., & Seal, C. E. (2010). What is stress? Concepts, definitions and applications in seed science. New Phytologist, 188(3), 655-673.. Soil Biology and Biochemistry. 2007;39(12):3187–90. doi:10.1016/j.soilbio.2007.06.025
6. Okumura M, Inoue K, Asakawa S, Kimura M. Salehi-Lisar, S. Y., & Bakhshayeshan-Agdam, H. (2016). Drought stress in plants: causes, consequences, and tolerance. In Drought Stress Tolerance in Plants, Vol 1 (pp. 1-16). Springer, Cham.. Soil Biology and Biochemistry. 2007;39(12):3187–90. doi:10.1016/j.soilbio.2007.06.025
7. Singh, S, Prasad, S, Yadav, V, Kumar, A, Jaiswal, B, Kumar, A, . & Dwivedi, D K (2018) Effect of drought stress on yield and yield components of rice (Oryza sativa L) genotypes Int J Curr Microbiol Appl Sci, 7, 2752-2759.
8. Sima Taheri. Wang, S., Liang, D., Li, C., Hao, Y., Ma, F., & Shu, H. (2012). Influence of drought stress on the cellular ultrastructure and antioxidant system in leaves of drought-tolerant and drought-sensitive apple rootstocks. Plant Physiology and Biochemistry, 51, 81-89.. AFRICAN JOURNAL OF BIOTECHNOLOGY. 2011;10(80). doi:10.5897/ajb11.352
9. Wang, S., Liang, D., Li, C., Hao, Y., Ma, F., & Shu, H. (2012). Influence of drought stress on the cellular ultrastructure and antioxidant system in leaves of drought-tolerant and drought-sensitive apple rootstocks. Plant Physiology and Biochemistry, 51, 81-89.. AFRICAN JOURNAL OF BIOTECHNOLOGY. 2011;10(80). doi:10.5897/ajb11.352
10. Jaleel CA, Sankar B, Murali PV, Gomathinayagam M, Lakshmanan GMA, Panneerselvam R. Water deficit stress effects on reactive oxygen metabolism in Catharanthus roseus; impacts on Ajmalicine accumulation. Colloids and Surfaces B: Biointerfaces. 2008;62(1):105–11. doi:10.1016/j.colsurfb.2007.09.026
11. Siti Aisha H, Saberi AR, Halim RA, Zaharah AR. Salinity effects on germination of forage Sorghumes. Journal of Agronomy. 2010;9(4):169–74. doi:10.3923/ja.2010.169.174
12. Lee S, Kim S, Park C. Salicylic acid promotes seed germination under high salinity by modulating antioxidant activity in Arabidopsis. New Phytologist. 2010;188(2):626–37. doi:10.1111/j.1469-8137.2010.03378.x
13. Mohammed SJ, Rosimah N. Impact of NACL, KCl, MCL2, MGSO4 and CACL2 on the leaf anatomy of cucumber (Cucumis sativus CV. MTI2). Plant Archives. 2020;20(1):2802-6.
14. RADHOUANE, Leila. Response of Tunisian autochthonous pearl millet (Pennisetum glaucum (L.) R. Br.) to drought stress induced by polyethylene glycol (PEG) 6000. African journal of biotechnology, 2007, 6.9.
15. Rahmani N. Effect of irrigation and nitrogen application on the quantity and quality of medicinal plant Marigold (Calendula officinalis L.). J. Afr. Agric. Res. 2006;6(9):2026-32.

16. Fathi, A. and Tari, D.B. (2016) 'Effect of drought stress and its mechanism in plants', International Journal of Life Sciences, 10(1), pp. 1–6. doi:10.3126/ijls.v10i1.14509.
17. Yigit N, Sevik H, Cetin M, Kaya N. Determination of the effect of drought stress on the seed germination in some plant species. Water Stress in Plants. 2016; doi:10.5772/63197
18. Farooq M, Wahid A, Kobayashi N, Fujita D, Basra SM. Plant drought stress: Effects, mechanisms and management. Sustainable Agriculture. 2009;153–88. doi:10.1007/978-90-481-2666-8_12
19. Ashraf M, Foolad MR. Roles of glycine betaine and proline in improving plant abiotic stress resistance. Environmental and Experimental Botany. 2007;59(2):206–16. doi:10.1016/j.envexpbot.2005.12.006
20. Tatar O, Gevrek MN. Influence of water stress on proline accumulation, lipid peroxidation and water content of wheat. Asian Journal of Plant Sciences. 2008;7(4):409–12. doi:10.3923/ajps.2008.409.412
21. Khan SH. Effect of drought stress on Tomato CV. Bombino. Journal of Food Processing & Technology. 2015;06(07). doi:10.4172/2157-7110.1000465
22. Abdul Q, Abdul R, Muhammad A, Matthew AJ. Water stress causes differential effects on germination indices, total soluble sugar and proline content in wheat (triticum aestivum L.) genotypes. African Journal of Biotechnology. 2011;10(64):14038–45. doi:10.5897/ajb11.2220
23. Manivannan P, Jaleel CA, Sankar B, Kishorekumar A, Somasundaram R, Lakshmanan GMA, et al. Growth, biochemical modifications and proline metabolism in helianthus annuus L. as induced by drought stress. Colloids and Surfaces B: Biointerfaces. 2007;59(2):141–9. doi:10.1016/j.colsurfb.2007.05.002
24. Benlaribi M, Monneveux P, Grignac P. Étude des caractères d'enracinement et de Leur rôle dans l'adaptation au déficit hydrique chez le Blé Dur (Triticum durum desf). Agronomie. 1990;10(4):305–22. doi:10.1051/agro:19900405
25. Perlikowski D, Czyżniejewski M, Marczak Ł, Augustyniak A, Kosmala A. Water deficit affects primary metabolism differently in two lolium multiflorum/festuca arundinacea introgression forms with a distinct capacity for photosynthesis and membrane regeneration. Frontiers in Plant Science. 2016;7. doi:10.3389/fpls.2016.01063
26. Ali Dib T, Monneveux PH, Araus JL. Breeding durum wheat for drought tolerance. Analytical, synthetical approaches, and their connections. InProceeding of International Symposium, June 4th-8th, Albena, Bulgaria, Agricultural Academy 1990 Jun 4 (pp. 224-240).
27. Adjab M. Recherche des traits morphologiques, physiologiqueset biochimiquesd'adaptation au déficithydrique chez différentsgénotypes de blédur (Triticum durum). Triticum durum. 2002.
28. Blum A. Osmotic adjustment and growth of barley genotypes under drought stress. Crop Science. 1989;29(1):230–3. doi:10.2135/cropsci1989.0011183x002900010052x
29. Ludlow MM, Muchow RC. A critical evaluation of traits for improving crop yields in water-limited environments. Advances in Agronomy. 1990;107–53. doi:10.1016/s0065-2113(08)60477-0
30. Młodzińska E. Survey of plant pigments: molecular and environmental determinants of plant colors. Acta Biologica Cracovienca Series Botanica. 2009;51(1):7-16.
31. Maxwell K, Johnson GN. Chlorophyll fluorescence—a practical guide. Journal of Experimental Botany. 2000;51(345):659–68. doi:10.1093/jexbot/51.345.659
32. Tembe KO, Chemining'wa GN, Ambuko J, Owino W. Effect of water stress on yield and physiological traits among selected African tomato (Solanum lycopersicum) land races.2017.
33. Hossain, M.D. A. Water stress tolerance tomato genotypes. M.Sc. Thesis, Department of Crop Botany Bangladesh agricultural university of Mymensingh. 2007.
34. Keyvan S. The effects of drought stress on yield, relative water content, proline, soluble carbohydrates and chlorophyll of bread wheat cultivars. J. Anim. Plant Sci. 2010 Jan 1;8(3):1051-60.
35. Al-Rahbawi, Shaima Mazi Jabbar. The effect of irrigation water quality and quantity on the growth and productivity of wheat (Triticum aestivum L) in Najaf Governorate. Master Thesis . College of Science . University of Kufa. 2012.

[DOR: 20.1001.1.26767414.2022.4.2.10.7]
[DOI: 10.52547/pbp.4.2.9]

36. Mohammad HA, Abu-dahi YM. THE ROLE OF FOLIAR APPLICATION OF MANGANES AND BORON ON WATER STRESS FOR MAIZE (Zea mays L.) 2. The Quantity and Quality characteristic for Plant . DASJ [Internet]. 2013 Dec. 30 [cited 2023 May 29];5(2):465-79. Available from: https://journal.djas.uodiyala.edu.iq/index.php/dasj/article/view/285
37. ZHANG Y, SHI Y, GONG H, ZHAO H, LI H, HU Y, et al. Beneficial effects of silicon on photosynthesis of tomato seedlings under water stress. Journal of Integrative Agriculture. 2018;17(10):2151–9. doi:10.1016/s2095-3119(18)62038-6
38. Gago J, Daloso DM, Carriquí M, Nadal M, Morales M, Araújo WL, et al. The photosynthesis game is in the "inter-play": Mechanisms underlying CO2 diffusion in leaves. Environmental and Experimental Botany. 2020;178:104174. doi:10.1016/j.envexpbot.2020.104174
39. ABOUSSOUAN-SEROPIAN C, PLANCHON C. Réponse de la photosynthèse de Deux Variétés de Blé à un déficit hydrique foliaire. Agronomie. 1985;5(7):639–44. doi:10.1051/agro:19850710
40. Oosterhuis DM, Walker S. Stomatal resistance measurement as an indicator of water deficit stress in wheat and soybeans. South African Journal of Plant and Soil. 1987;4(3):113–20. doi:10.1080/02571862.1987.10634956
41. Kutlu İM, Turhan E, Yorgancilar Ö, Yorgancilar A. Differences of physiological parameters and sucrose metabolism in bread wheat genotypes exposed to drought stress. August 2021. 2020;31(4). doi:10.36899/japs.2021.4.0296
42. Zhang YJ, Xie ZK, Wang YJ, Su PX, An LP, Gao H. Effect of water stress on leaf photosynthesis, chlorophyll content, and growth of Oriental Lily. Russian Journal of Plant Physiology. 2011;58(5):844–50. doi:10.1134/s1021443711050268
43. George-Jaeggli B, Mortlock MY, Borrell AK. Bigger is not always better: Reducing Leaf area helps stay-green sorghum use soil water more slowly. Environmental and Experimental Botany. 2017;138:119–29. doi:10.1016/j.envexpbot.2017.03.002
44. Austin RB. Stress responses in plants: Adaptation and acclimation mechanisms. edited by R. G. Alscher and J. R. Cumming. New York: Wiley-Liss (1990), pp. 407, US$ 99.50. ISBN 0-471-56810-4. Experimental Agriculture. 1991;27(4):447–447. doi:10.1017/s0014479700019530
45. Hirasawa T, Wakabayashi K, Touya S, Ishihara K. Stomatal responses to water deficits and abscisic acid in leaves of sunflower plants (helianthus annuus L.) grown under different conditions. Plant and Cell Physiology. 1995;36(6):955–64. doi:10.1093/oxfordjournals.pcp.a078866
46. Sanchez-Diaz MF, Kramer PJ. Behavior of corn and sorghum under water stress and during recovery. Plant Physiology. 1971;48(5):613–6. doi:10.1104/pp.48.5.613
47. Hosker RP, Lindberg SE. Review: Atmospheric deposition and plant assimilation of gases and particles. Atmospheric Environment (1967). 1982;16(5):889–910. doi:10.1016/0004-6981(82)90175-5
48. Caird MA, Richards JH, Donovan LA. Nighttime stomatal conductance and transpiration in C3 and C4 plants. Plant Physiology. 2007;143(1):4–10. doi:10.1104/pp.106.092940
49. Whitmore JS. Drought management on farmland. Springer Science & Business Media; 2000 Jan 31
50. Hopkins WG. Photosynthesis and respiration [Internet]. Chelsea House. 2006;Available from: https://books.google.com/books/about/Photosynthesis_and_Respiration.html?id=Qt1buAAACAAJ
51. BLACKMAN PG, DAVIES WJ. Root to shoot communication in maize plants of the effects of soil drying. Journal of Experimental Botany. 1985;36(1):39–48. doi:10.1093/jxb/36.1.39
52. Comas LH, Becker SR, Cruz VM, Byrne PF, Dierig DA. Root traits contributing to plant productivity under drought. Frontiers in Plant Science. 2013;4. doi:10.3389/fpls.2013.00442
53. Benlaribi M. Adaptation au déficit hydrique chez le blé dur (Triticum durum Desf.): Etude des caractères morphologiques et physiologiques (Doctoral dissertation, Thèse de Doctorat d'Etat, ISN-Université de Constantine).1990.

54. Nahar K, Gretzmacher R. Response of shoot and root development of seven tomato cultivars in hydrophonic system under water stress. Academic Journal of Plant Sciences. 2011;4(2):57-63.
55. Brisson N. On the importance of soil evaporation and rainfall interception in irrigation scheduling. InInternational Conference 1996 Nov 3. American Society of Agricultural Engineers.
56. Ait Kaki Y. Contribution à l'étude des mécanismes morpho physiologiques de tolérance au stress hydrique sur 5 variétés de blé dur (Triticum durum Desf.). Mémoire de Magistère. Université d'Annaba, p130. 1993.
57. Akter N, Rafiqul Islam M, Abdul Karim M, Hossain T. Alleviation of drought stress in maize by exogenous application of gibberellic acid and cytokinin. Journal of Crop Science and Biotechnology. 2014;17(1):41–8. doi:10.1007/s12892-013-0117-3
58. Fereres E. Variability in adaptive mechanisms to water deficits in annual and perennial crop plants. Bulletin de la Société Botanique de France Actualités Botaniques. 1984;131(1):17–32. doi:10.1080/01811789.1984.10826629
59. Nemmar M. Contribution à l'étude de la résistance à la sécheresse chez les variétés de blédur (Triticum durum Desf) et de blétendre (TriticumaestivumL). Evaluation des teneurs en proline au coursdu cycle de développement (Doctoral dissertation, Thèse de doctorat. Montpellier. p: 108).
60. Wahb-Allah MA, Alsadon AA, Ibrahim AA. Drought tolerance of several tomato genotypes under greenhouse conditions. World Applied Sciences Journal. 2011;15(7):933-40.
61. Casal JJ. Phytochrome a enhances the promotion of hypocotyl growth caused by reductions in levels of phytochrome B in its far-red-light-absorbing form in light-grown Arabidopsis thaliana. Plant Physiology. 1996;112(3):965–73. doi:10.1104/pp.112.3.965
62. Grignac P. Contraintes de l'environnement et l'elaboration du rendement dans la zone mediterraneennefrancaise In: L'elaboration du rendement des cultures ceralieres. InColloque Franco-Roumain, Clermont Ferrand 1986 Mar (pp. 17-19).
63. Ozbahce A, Tari AF. Effects of different emitter space and water stress on yield and quality of processing tomato under semi-arid climate conditions. Agricultural Water Management. 2010;97(9):1405–10. doi:10.1016/j.agwat.2010.04.008
64. Fadol, H. A., Ahamed, S. H., &Eldie, Y. DEffect of Water Stress on Growth and Yield of different faba bean varieties (Viciafaba L.) in Kabkabia Suburb North Darfur.2017. http://dx.doi.org/10.13140/RG.2.2.33077.83681